Characterizing Arctic plant traits with near-surface and unmanned aerial system (UAS) remote sensing

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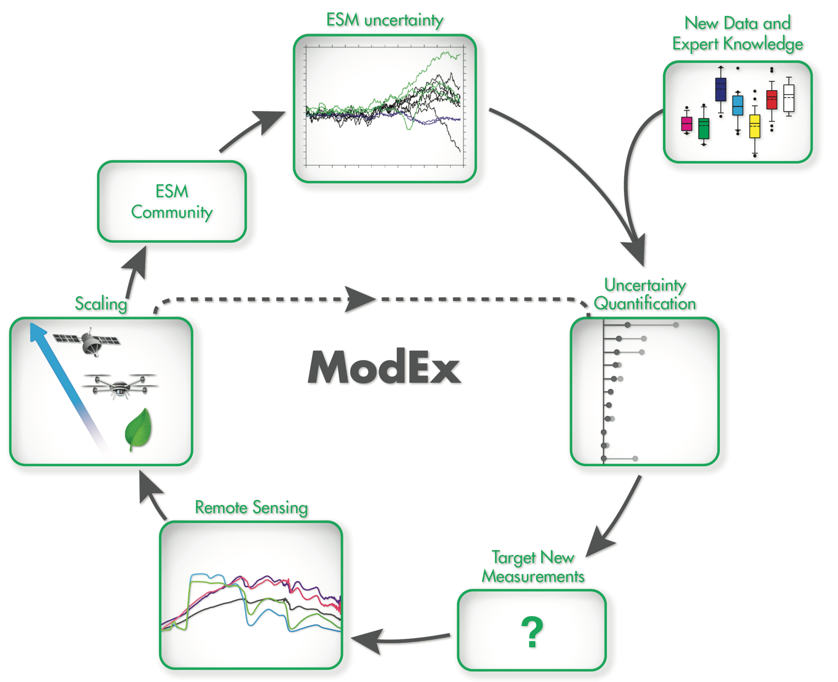
Background

Modeling the fluxes and pools of carbon, water and energy is an essential part of understanding and quantifying the impacts of global change on terrestrial ecosystems. Process models, such as terrestrial biosphere and Earth System Models require detailed information on vegetation states and properties to properly simulate these fluxes and pools as well as to minimize model projection uncertainties.



A major focus of our research is on the use of remote sensing data (from leaf to grid scale) to enable the mapping of key plant traits and canopy properties related to ecosystem structure and functioning. These spatially and temporally rich trait maps are then used to iteratively inform modeling activities across the Arctic within a *ModEx* framework (Fig 1).

Figure 1. Our *ModEx* approach to study processes that have a global impact, focused on ecosystems that are poorly understood, sensitive to global change, and inadequately represented models.

Remote sensing

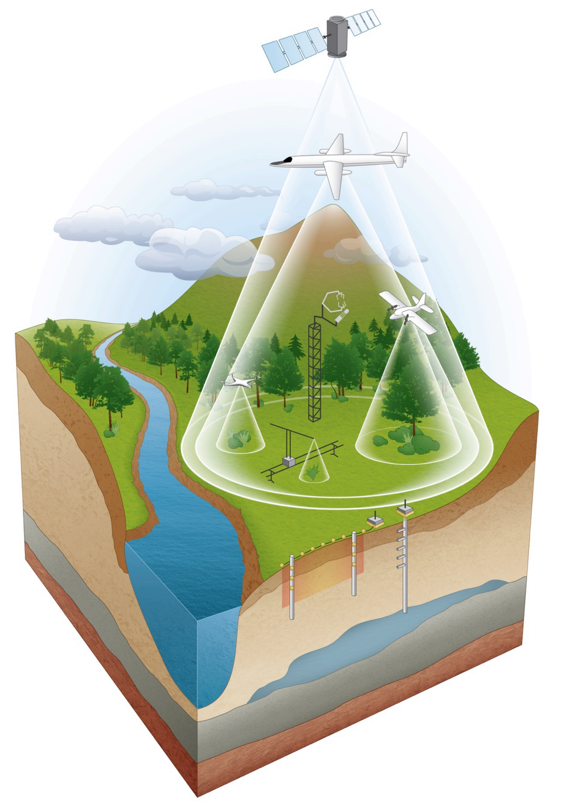
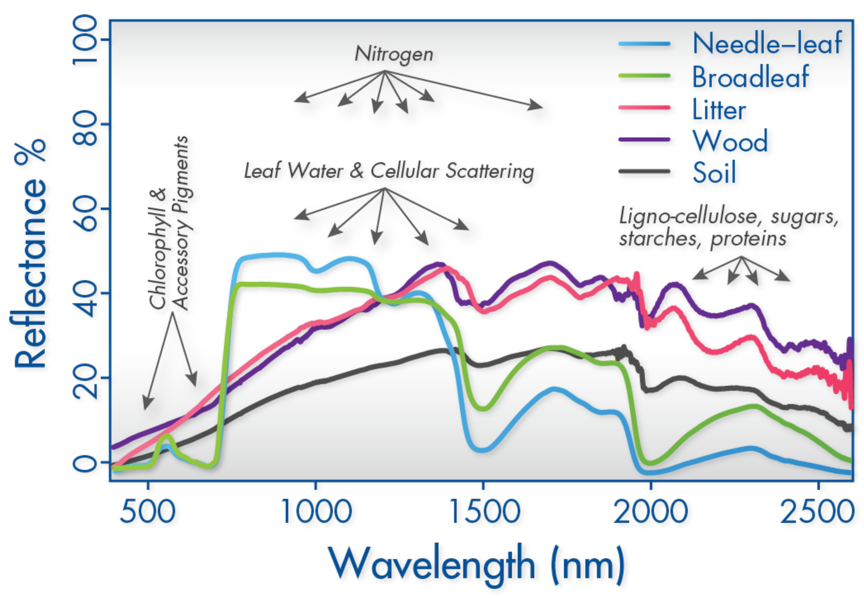


Figure 2. Near-surface (e.g. tram) to UAS and manned aerial platforms can fill a critical gap in the scaling of plant properties and traits from the leaf to the synoptic grid/satellite scale and enable rapid and targeted data collection activities to correspond with field campaigns

Figure 3. Remote sensing can be used to remotely measure plant traits. Specifically leaf and imaging spectroscopy data within the visible, near-infrared (NIR), and shortwave infrared (SWIR) provides the best opportunity to measure a broad range of key plant biochemical and physiological traits across scales.



NGEE-Arctic tram (2015 – present)

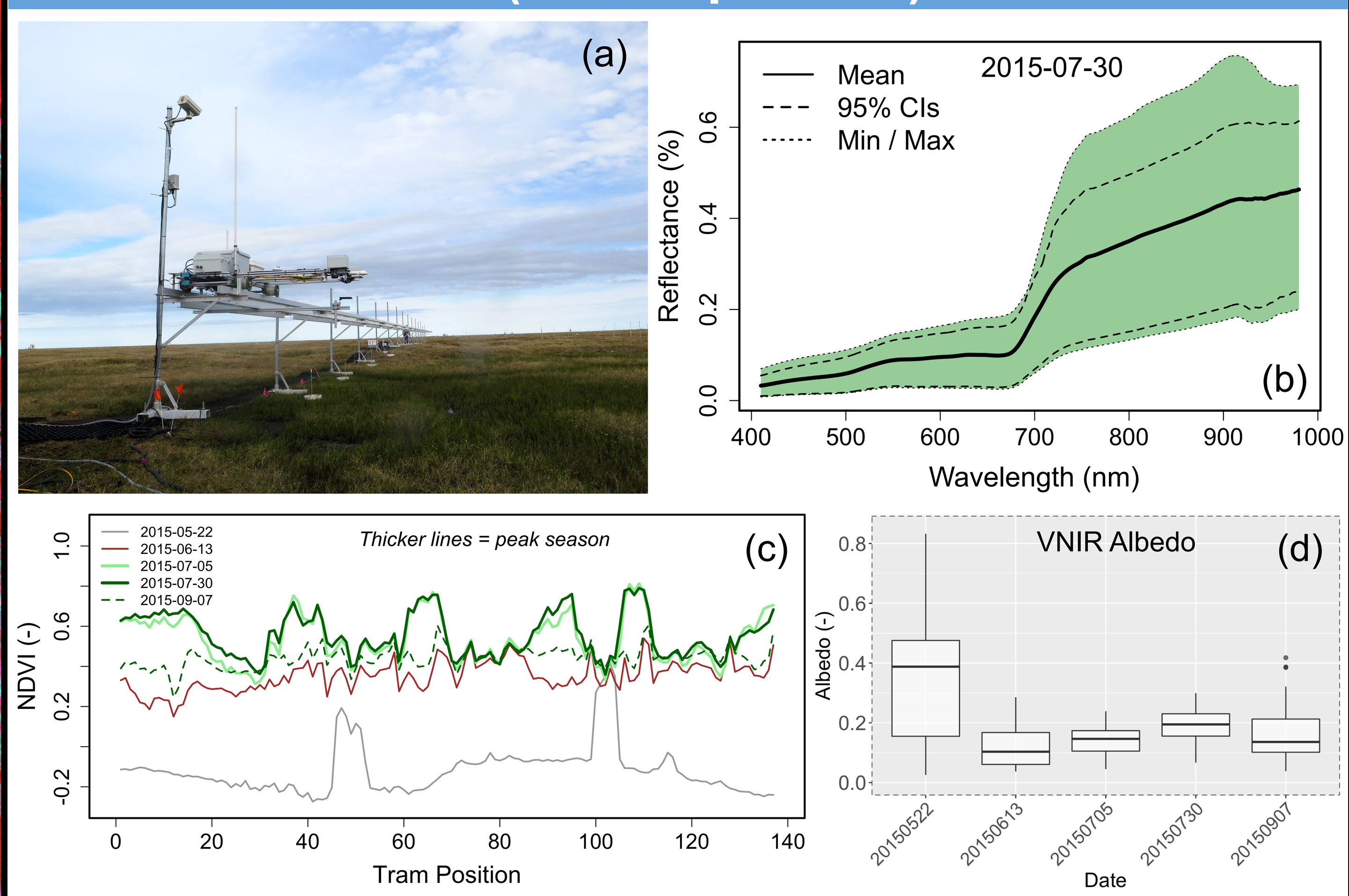


Figure 4. The NGEE-Arctic automated tram platform (a) collects surface energy balance measurements (e.g. albedo, net radiation), TIR and RGB photos, as well as spectral properties at 137 stops along the 70 meter track. The UniSpec-DC dual upwelling/downwelling spectrometer is being used to measure spatial (b) and seasonal variation of canopy reflectance, spectral vegetation indices, (c) and visible through near-infrared (VNIR) albedo (d). The tram is also located within the NGEE-Arctic eddy covariance tower (not pictured)

UAS platform and design

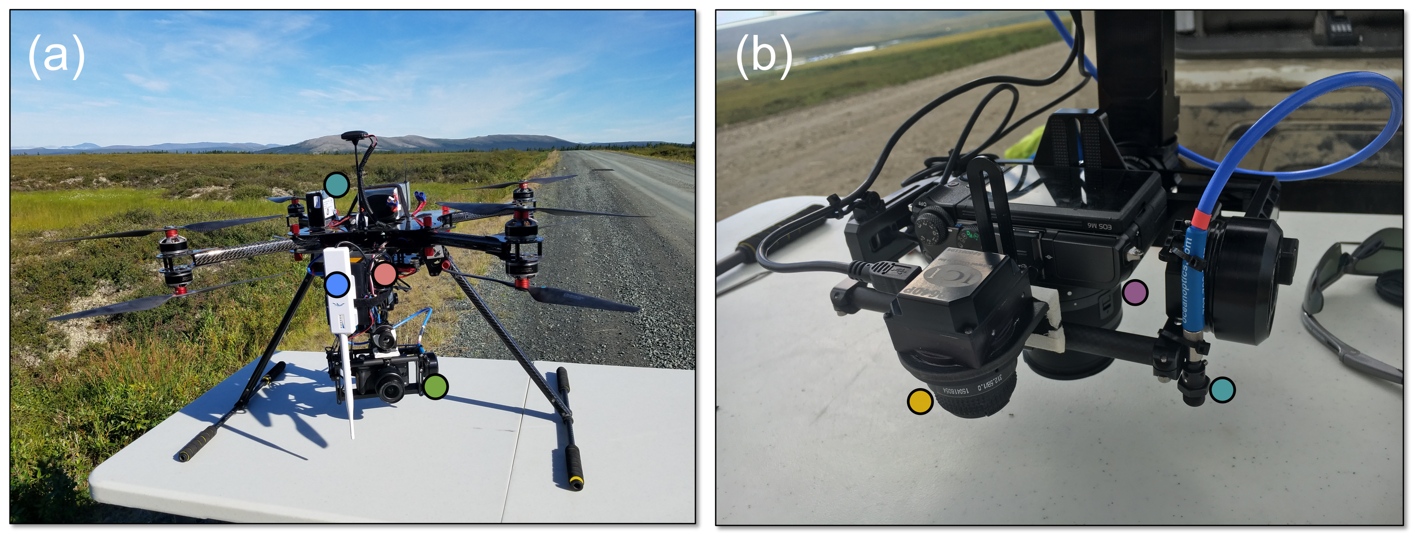


Figure 5. (a) Our *Osprey* heavy-lift (3-5kg payload capacity, depending on motor configuration) octocopter UAS (FAA Civil Aviation Registry No. T0056572) is built from a CarbonCore carbon fiber airframe together with a 3D Robotics PixelHawk flight control computer and a 3-axis programmable brushless gimbal. (b) Close up of our mixed-footprint instrument suite (Fig. 6): a high-resolution digital camera, dual spectrometers for downwelling and upwelling irradiance measurements (to calculate surface reflectance), and a thermal infrared camera (see Fig. 7)

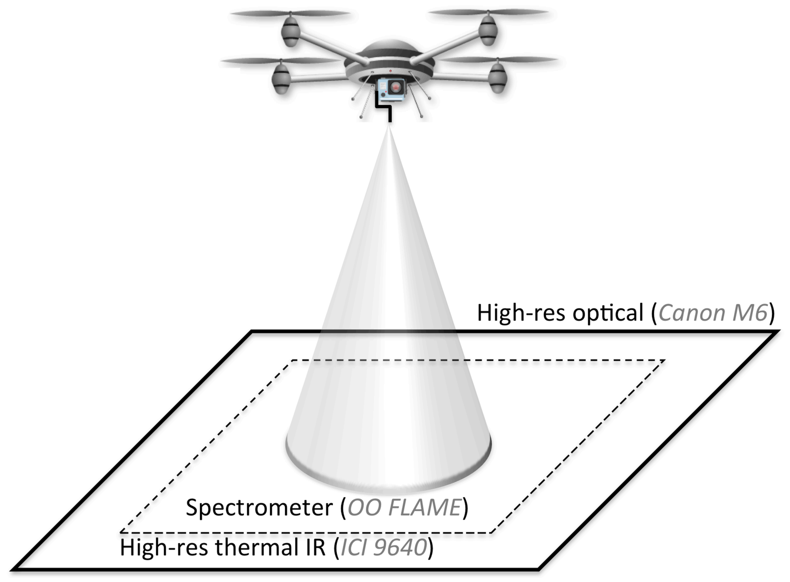
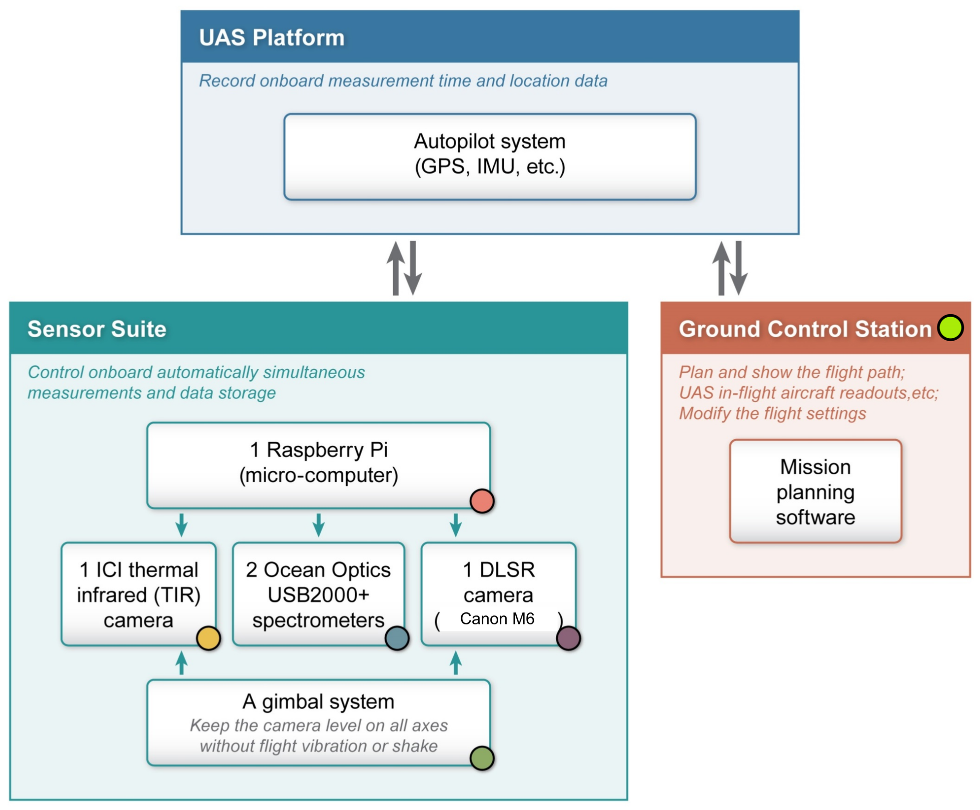


Figure 6. Our UAS instrument suite contains a mixture of both point and imaging hardware. We have developed a software automation package (Figs. 7 & 8) to facilitate collection and are building a processing workflow to generate individual and a data-fusion product for each flight

Figure 7. Schematic of our automation and instrument control which uses a sophisticated open-source flight control computer together with state-of-the-art remote sensing instrumentation and a custom designed software package (Fig. 8) to manage our scientific missions and instrument operations



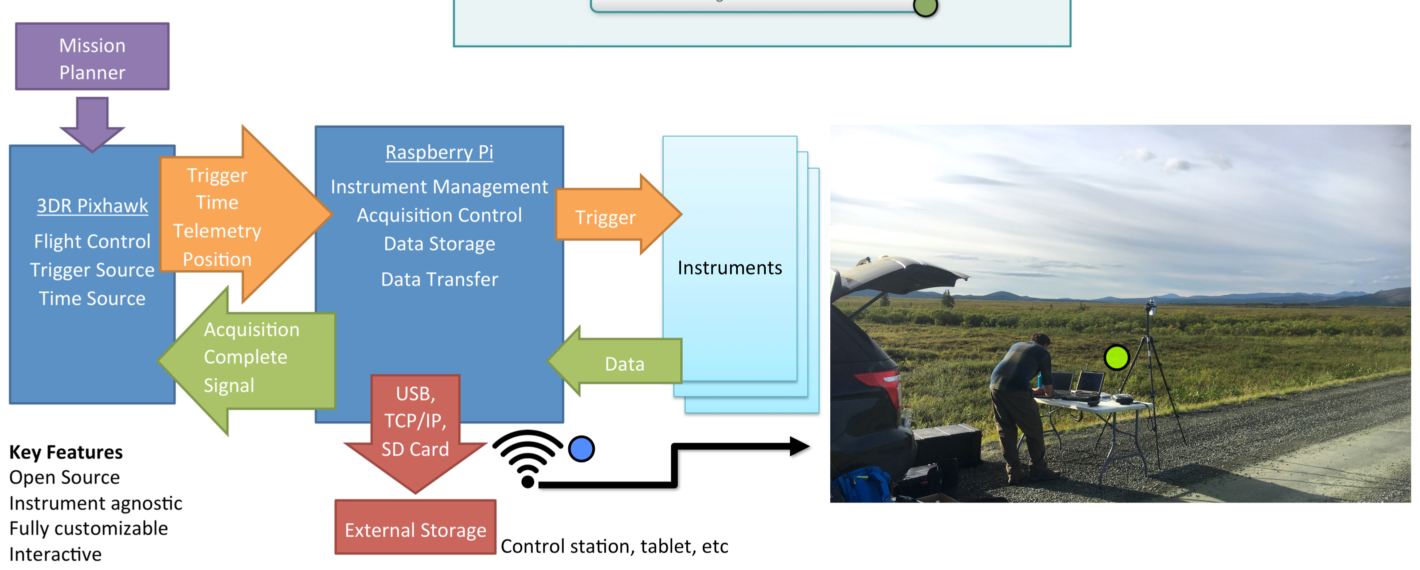


Figure 8. Our custom-designed Modular Data Collection System (MoDaCS) links UAS mission planning and flight control to the onboard instrument packages enabling automated data acquisition linked to customizable flight plans and real-time monitoring. MoDaCS is written in Python with a graphical user interface (GUI) built with the Qt framework to provide graphical monitoring and interactive plotting during and following data collection (e.g. Fig. 9)

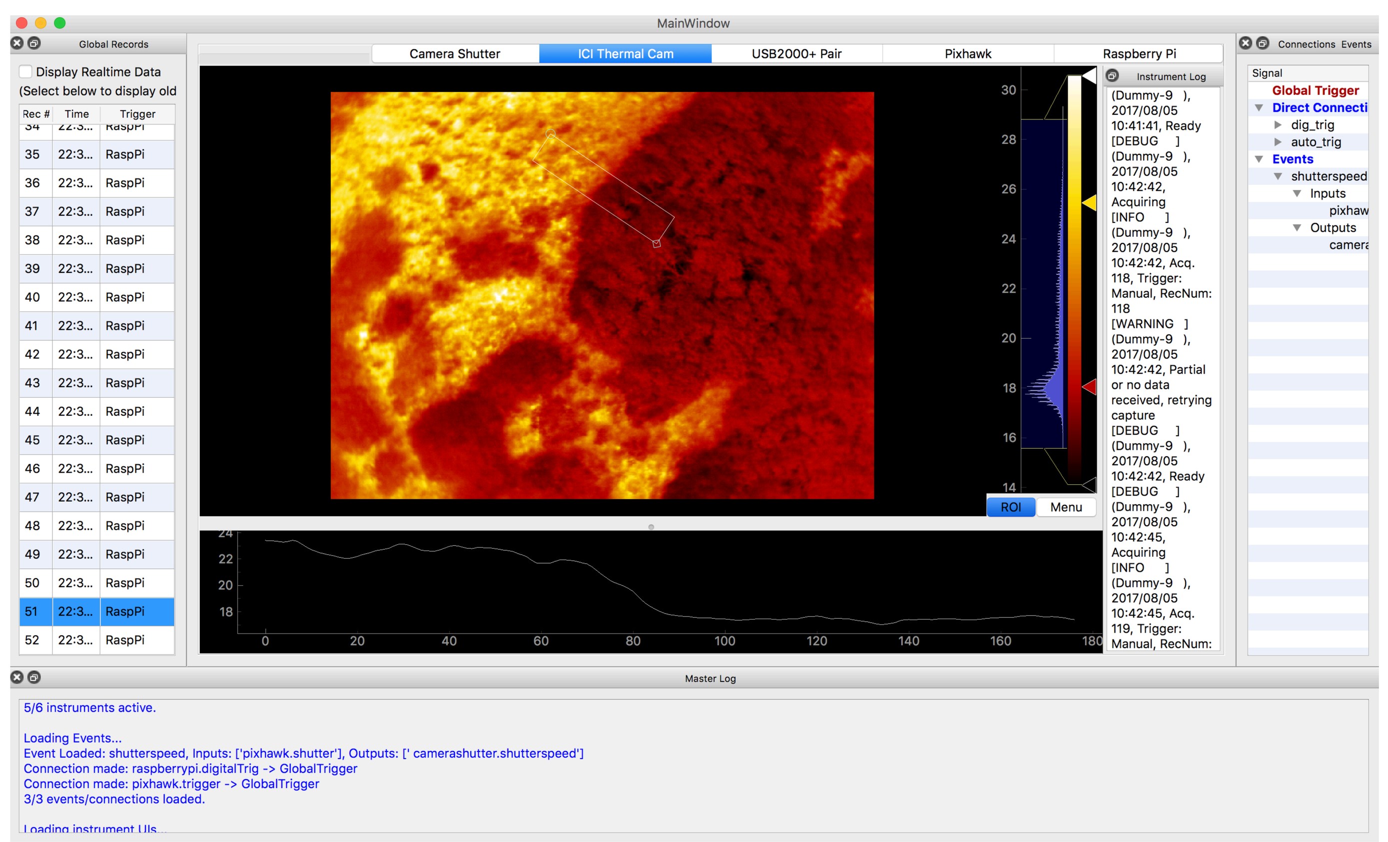


Figure 9. An example high-resolution thermal image of shrub tussock tundra at the Teller study site displayed in our MoDaCS software. The white box region-of-interest (ROI) and corresponding temperature variation is shown below the image

Nome 2017 UAS Deployment

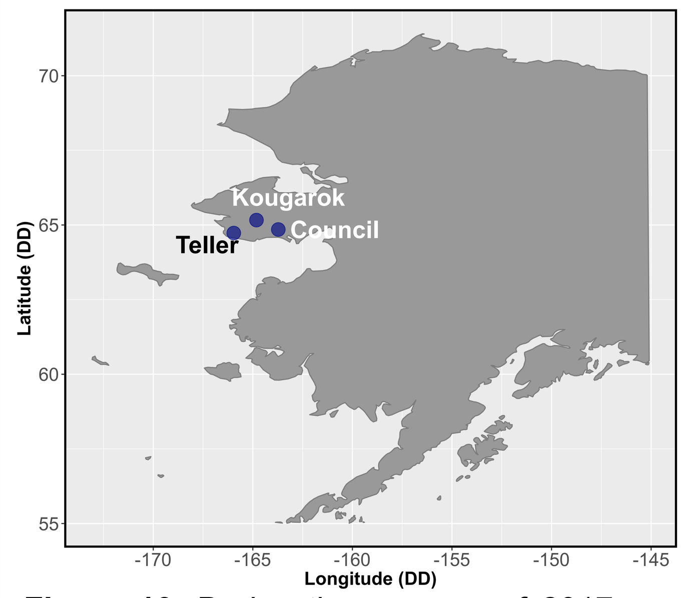


Figure 10. During the summer of 2017 we deployed our platform (Fig. 5) at the NGEE-Arctic Seward Peninsula sites

Figure 11. Flying the *Osprey* platform at the Teller study site

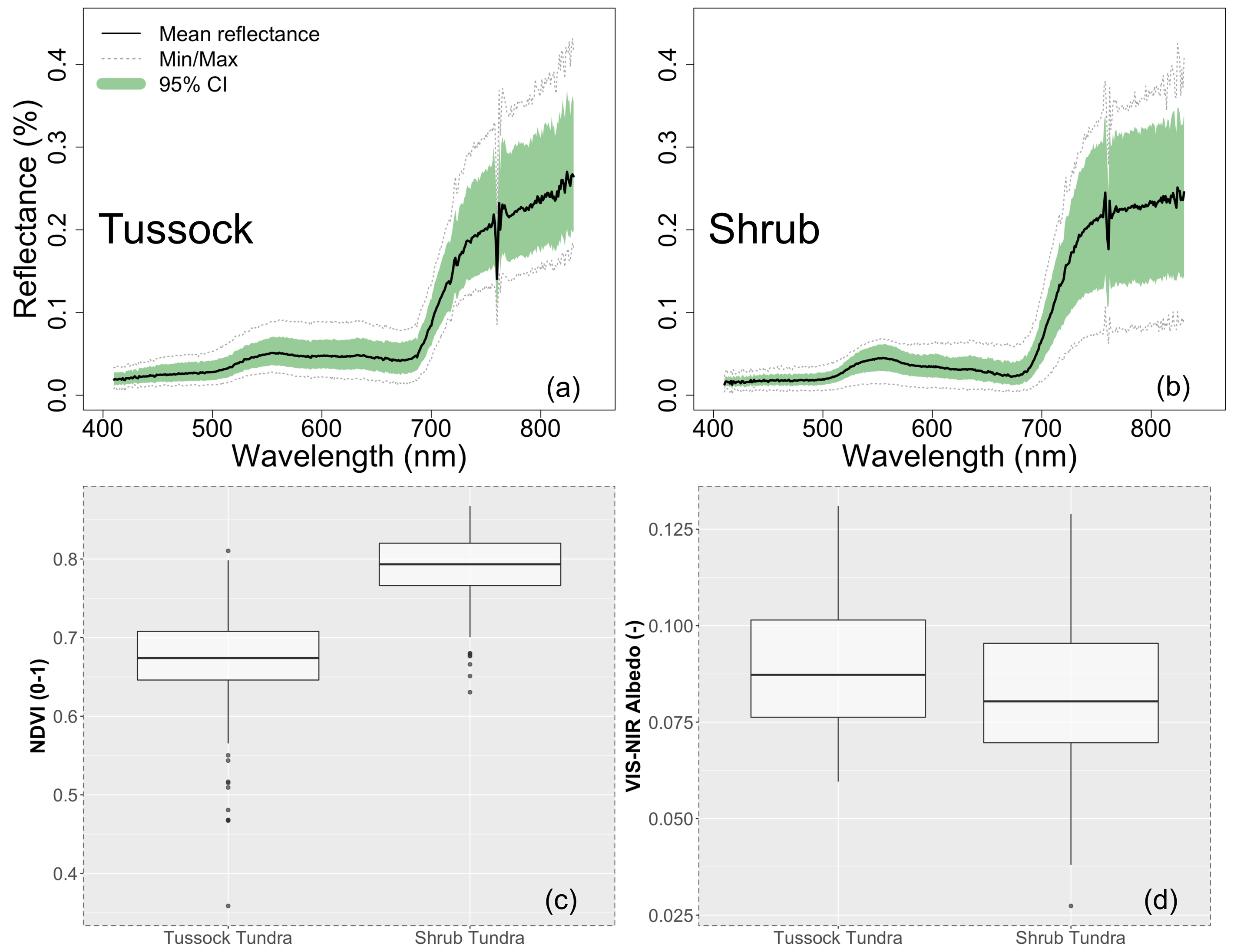


Figure 12. Spectral variation across a tussock tundra (a) and shrub tundra (b) landscape at the Council study site (Fig. 10) measured from our UAS platform. The corresponding patterns in NDVI (c) and VNIR spectral albedo (d)

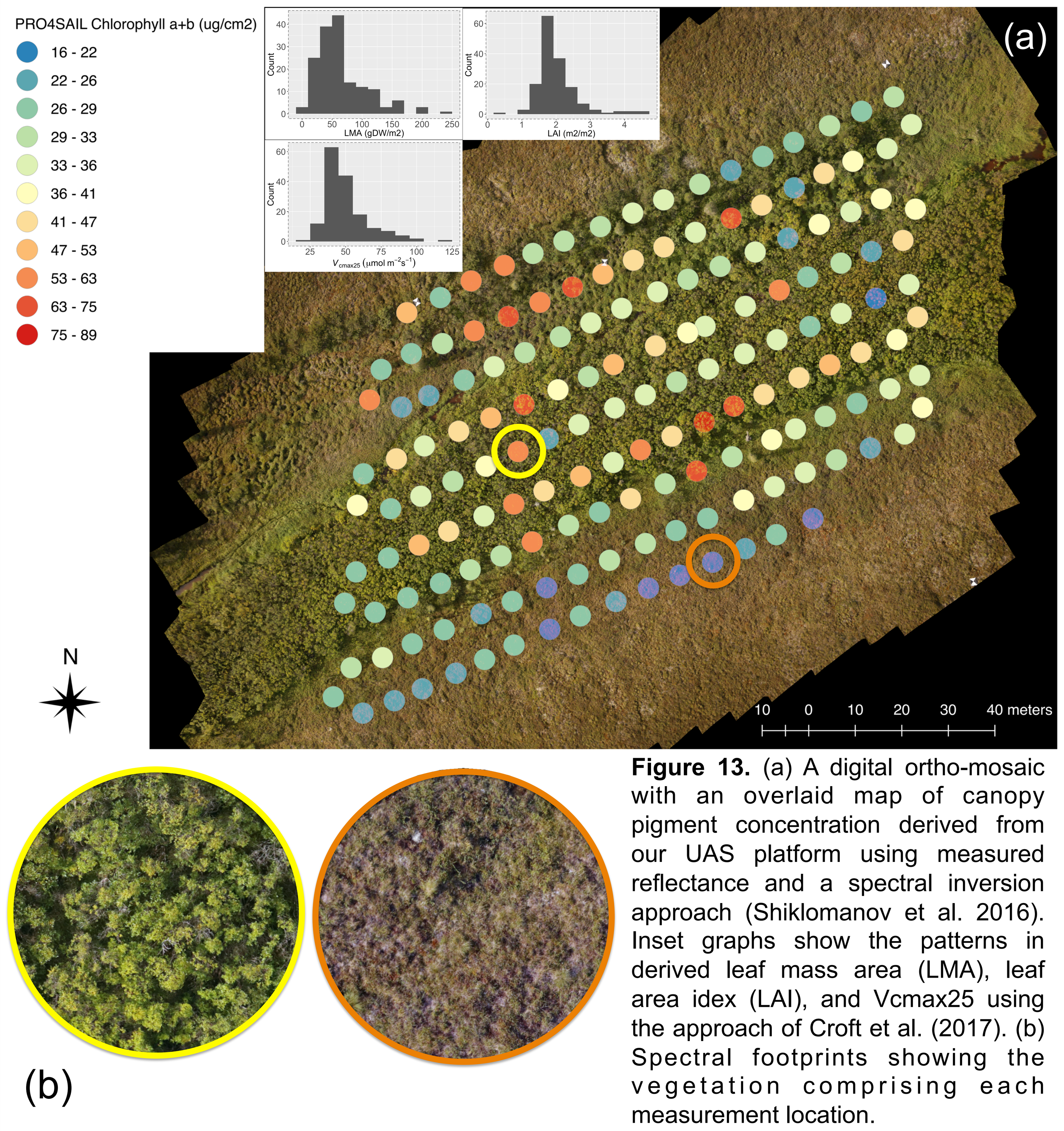


Figure 13. (a) A digital ortho-mosaic with an overlaid map of canopy pigment concentration derived from our UAS platform using measured reflectance and a spectral inversion approach (Shiklomanov et al. 2016). Inset graphs show the patterns in derived leaf mass area (LMA), leaf area index (LAI), and Vcmax25 using the approach of Croft et al. (2017). (b) Spectral footprints showing the vegetation comprising each measurement location.

Next steps

- Finalize data processing workflows and provide remote sensing (tram/UAS) data products to the NGEE portal and publish results
- 2018 re-deployment in Barrow/Nome to continue mapping of key areas at each study site
- Link with NASA ABoVE to provide watershed-scale trait mapping

References:
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Croft, H., J. M. Chen, X. Luo, P. Bartlett, B. Chen, and R. M. Staebler. 2017. Leaf chlorophyll content as a proxy for leaf photosynthetic capacity. Global Change Biology **23**:3513-3524.